Issn 0973-9777 Volume-6 Number-2 March-April 2012

The Indian Journal of Research Anvikshiki

Bi-monthly International Journal of all Research

www.onlineijra.com

Engineering and Technology

Anvikshiki
The Indian Journal of Research
Bi-Monthly International Journal of All Research

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(Letter No.V-34564,Reg.533/2007-2008)
B-32/16-A-2/1,Gopalkunj,Nariya,Lanka
Varanasi,U.P.,India

Anvikshiki
The Indian Journal of Research
Volume 6 Number 2 March 2012

Engineering and Technology
Papers

PRINT ISSN 0973-9777,WEBSITE ISSN 0973-9777

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(CENTRE OF ADVANCED STUDY & DST DEPARTMENT UNDER FIST)
INSTITUTE OF TECHNOLOGY
(Varanasi – 221005)
(Established by Parliament by Notification No 225 of 1916)

Message

Scientific discoveries and advancement affect our lives by providing new policies and regulations that provide broad national direction and by new products that enhance our lives. Technology and engineering translate scientific knowledge into action. At the same time, technological innovations often require further research into materials, devices and processes. Engineers use the knowledge of science, mathematics, economics and appropriate experience to find suitable solutions to the problems and helps in creating an appropriate mathematical model for analysis.

This special issue on Engineering and Technology 2012 of Anvikshiki brings together the latest developments in technology and gives a base for the future work to be done in respective areas.

I wish the journal to be a great success.

Bhawna Verma
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Message

I express my sincere gratitude to the editorial board of prestigious journal ANVIKSHIKI for believing in my technical competencies and choosing me as a reviewer of special issue on Engineering and Technology 2012. I understand that with great role comes great responsibilities. I will try to fulfill this highly valued responsibility with best of my technical knowledge and human values. This journal has been a guiding beacon for scientific community for numerous years & has gained the prestige due to it's original & rich articles. The contribution of ANVIKSHIKI in field of scientific research is immense.

I wish for the phenomenal success of special issue on Engineering and Technology,2012 of ANVIKSHINKI.

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Editorial Note

As my nomination as an Subject Expert and Editor for this Special Issue on Engineering & Technology 2012, I have worked a lot to make it successful. I do whatever task is at hand to the best of my ability. I take pride in my work and give hundred percent every time. For those submissions that were not suitable for publication, we tried to let authors know very quickly of our decision, giving them a chance to submit their manuscript to another journal if they so desire. I am fully aware that the prestige and quality of an ANVIKSHIKI Journal depends upon the altruistic participation of reviewers and the fairness and promptness with which the review process is conducted. In this regard, I wish to express my sincere gratitude to all board members for their nice cooperation and sustained effort. However, because of the increased number of submissions and the diversity of research fields involved, we have a difficult task ahead of us requiring a more rapid tempo of review. At the same time, from now on the authors themselves should assume their own inescapable responsibilities. The editor will return immediately any manuscript that is incomprehensible to reviewers on account of substandard grammar and syntax.

Finally, it is a pleasure to thank my Editor in chief for their nice cooperation and valuable suggestion. Now, we all look forward to embarking in a journey that can take ANVIKSHIKI on to the next plateau of excellence.

I hope you will enjoy reading this issue and we welcome your feedback .

With best regards,

Jyoti Prakash

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Best regards,

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NAME OF JOURNAL

Global Journal of Engineering and Technology (GJET)

ISSN

ISSN ……… in process

FREQUENCY

Six-monthly

LANGUAGE

English

LAUNCH DATE

July 1,2012

EDITOR-IN-CHIEF

Dr. Maneesha shukla, Gopalkunj, flat no 1, Naria, Lanka , Varanasi, up, India. maneeshashukla76@rediffmail.com

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Letter No.V-34564,Reg.533/2007-2008 INDIAN JOURNAL OF RESEARCH(2012)**6,81-87**
ANVIKSHIKI ISSN 0973-9777 Advance Access publication 16 Jan. 2012

NONLINEAR CONTROL DESIGN USING TECHNIQUES OF FUZZY LOGIC SYSTEM

SHEKHAR YADAV*, SANJAY KUMAR** AND J.P.TIWARI***

Declaration

The Declaration of the authors for publication of Research Paper in The Indian Journal of Research Anvikshiki ISSN 0973-9777 Bi-monthly International Journal of all Research: We, *Shekhar Yadav, Sanjay Kumar and J.P.Tiwari* the authors of the research paper entitled NONLINEAR CONTROL DESIGN USING TECHNIQUES OF FUZZY LOGIC SYSTEM declare that , We take the responsibility of the content and material of our paper as We ourself have written it and also have read the manuscript of our paper carefully. Also, We hereby give our consent to publish our paper in Anvikshiki journal , This research paper is our original work and no part of it or it's similar version is published or has been sent for publication anywhere else.We authorise the Editorial Board of the Journal to modify and edit the manuscript. We also give our consent to the Editor of Anvikshiki Journal to own the copyright of our research paper.

Abstract

This paper addresses the nonlinear control design problem for a single tank, liquid level system. In this paper, a fuzzy controller is designed and simulated exclusively to control a single tank problem and also utilizing the advantages of the conventional control i.e. PID control. The controllers also can be specifically run under the circumstance of system disturbances. To achieve these objectives, a prototype of water level control system has been built and implementations of fuzzy logic control algorithms are performed. In fuzzy logic control, Sugeno model is used to control the system.
Keywords: nonlinear control, fuzzy logic control, rule base, PID control.

I. Introduction

In process control systems nonlinearity is the rule rather than the exception. Most control loops such as pressure, temperature, composition, etc., are significantly nonlinear [1,6]. This may be because of nonlinearity due to control valves, or on account of variations in process gain, time constant, and dead time. Water level and air pressure control[2] is a classical problem in control engineering. These problems are usually analyzed in literature in separate cases, mathematical models are defined for water level or air pressure systems, and digital control methods. The control problem becomes more complex if water level and air pressure control are considered in one system. In such case the change of water level or air pressure set point, changes the dynamics of the whole system and this requires the adaptation of controller parameters. When water flows through pipes, the silt gathers on inner side decreasing its diameter and

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herewith the amount of flowing water. This feature changes the dynamics of the flow system and stipulates an adaptation of controller parameters.

In this paper a fuzzy controllers[1,4,5] are introduced as an alternative for the water level and air pressure control. In the absence of sufficiently precise process mathematical model and in the presence of non linearity, fuzzy logic based control[3] usually have an advantage over conventional PID control. The primary control problem, considered with this control system, is regulating water level at the specified set points.

II. Modeling of Single Tank System

It is important to understand the mathematics of how the single tank system behaves. This is system modeling and it is very important part of control system analysis. The single tank system is shown in Fig. 1. The system model is determined by relating the flow Q_i into the tank to the flow Q_o leaving through the valve at the tank bottom. Using a balance of flows equation on the tank,

$$Q_i - Q_o = A\frac{dh}{dt} \tag{1}$$

where A is the cross section area of tank and H is the height of the fluid in the tank.

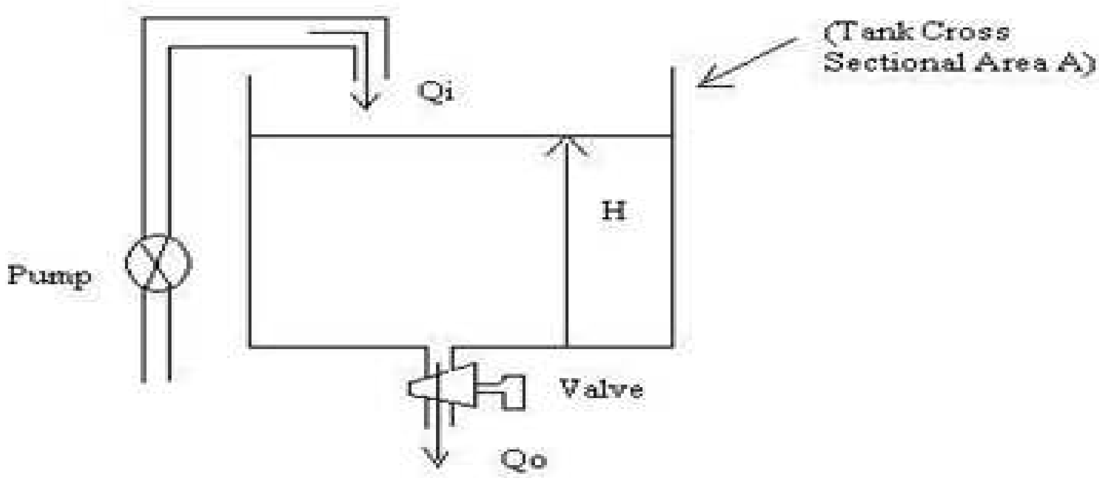

Fig. 1 *A Single Tank Fluid Level System*

If the valve is assumed to behave like an idea sharp edged orifice, than the flow through the valve will be related to the fluid level in the tank, by the expression-

$$Q_o = C_d a\sqrt{2gH} \tag{2}$$

where a is the cross sectional area of orifice, C_d is called the discharge coefficient of the valve. This coefficient takes into account all fluid characteristics, losses and irregularities in the system such that the two sides of the equation balance, and g is the gravitational constant (9.8 m/s^2). Equation (2) assumes C_d is constant so that Q_o has a nonlinear relationship to the level H for all possible operating condition. Ideally the nonlinear relation is the square root, but in a practical valve there is more complex nonlinear equation. Combining eqn. (1) and eqn. (2)-

$$Q_i = A\frac{dh}{dt} + C_d a\sqrt{2gH} \tag{3}$$

This equation is the mathematical model that describes the system behavior, and again we see nonlinear things in the system model. In the tank level problem the nonlinearity is smooth and can be made linear at a particular operating level H by using the slope of the nonlinearity at H.

III. PID Controller for Single Tank System

Proportional-Integral-Derivative (PID) control is the most common control algorithm used in industry and has been universally accepted in industrial control. The popularity of PID controllers can be attributed partly to their robust performance in a wide range of operating conditions and partly to their functional simplicity, which allows engineers to operate them in a simple, straightforward manner. The ideal continuous PID controller is-

$$u = K_p \left(e + \frac{1}{T_i} \int_0^t e * d\tau + T_d \frac{de}{dt} \right) \tag{4}$$

where u is the control variable, e is the control error, the constant K_p is proportional gain, T_i is the integral time, and T_d is the derivative time.

IV. Fuzzy Logic Control for Single Tank System

The fuzzy sets concept was proposed by Zadeh in 1965. The fuzzy algorithm can make human knowledge into the rule base to control a plant with linguistic descriptions. It relies on expert experience instead of mathematical models. The advantages of fuzzy control include good popularization, high faults tolerance, and suitable for nonlinear control systems. A fuzzy controller design has four parts, fuzzification, control rule base, fuzzy inference, and defuzzification. The block diagram of the fuzzy control system is shown in Fig. 2.

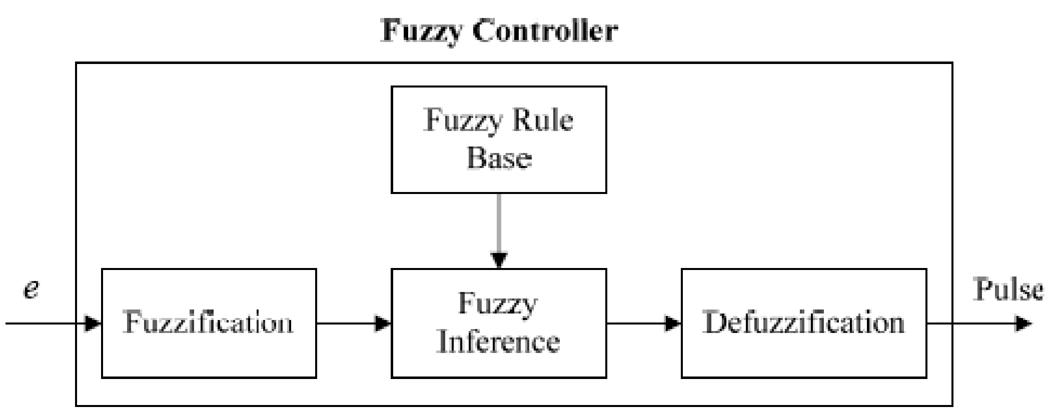

Fig. 2. *Block diagram of the fuzzy control.*

In Fuzzy control, two inputs for the system are chosen. They are an error (e) and an error derivative ($\dot{e}$). The error is calculated by taking the difference between the reference signal and the current water height. The error derivative is calculated by subtracting a previous error from the current error. The output of the system is a voltage that is sent to a servo motor to control the valve 1. The Sugeno model is used in the system. The Sugeno model is computationally efficient, and works well with optimization and adaptive techniques, so it is popular for control problems, in particular for dynamic nonlinear systems. The basic function of rule base is to represent in a structured way the control policy in the form of a set of production rules such as :

if <Process State> then <Control Output>

The *if* part of such a rule is called rule antecedent and is a description of a process state in terms of a logical combination of atomic fuzzy propositions. The *'then'* part of the rule is called rule consequent. The fuzzy logic control rules are expressed under the following form:

Rule.1 If <level is okay> then <valve is no change>

Rule.2 If <level is low> then <valve is open fast>

Rule.3 If <level is high> then <valve close fast>

Rule.4 If <level is good> and <rate is negative> then <valve is close slow>

Rule.5 If <level is good> and <rate is positive> then <valve is open slow>

The first three rules are not sufficient, because the water level tends to oscillate around the desired level. The water level's rate of change is introduced to slow down the valve movement when it get close to the right level.

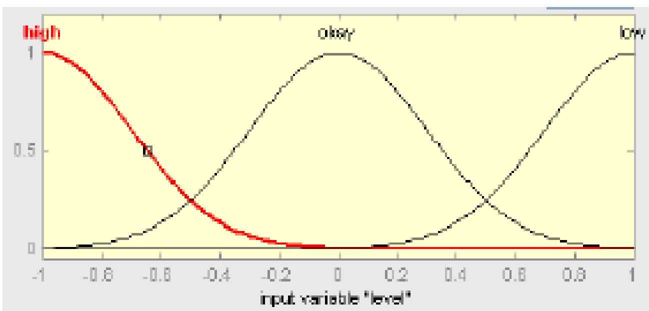

Fig.3 *Error Membership Function*

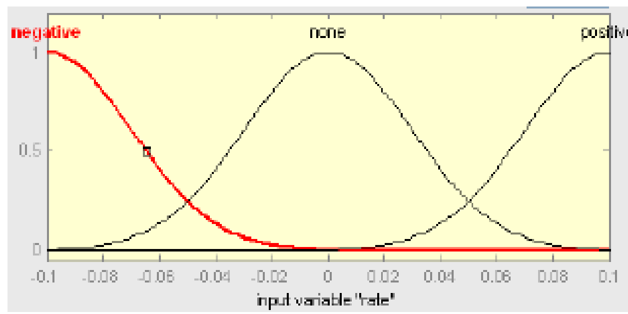

Fig.4 Change in Error Membership Function

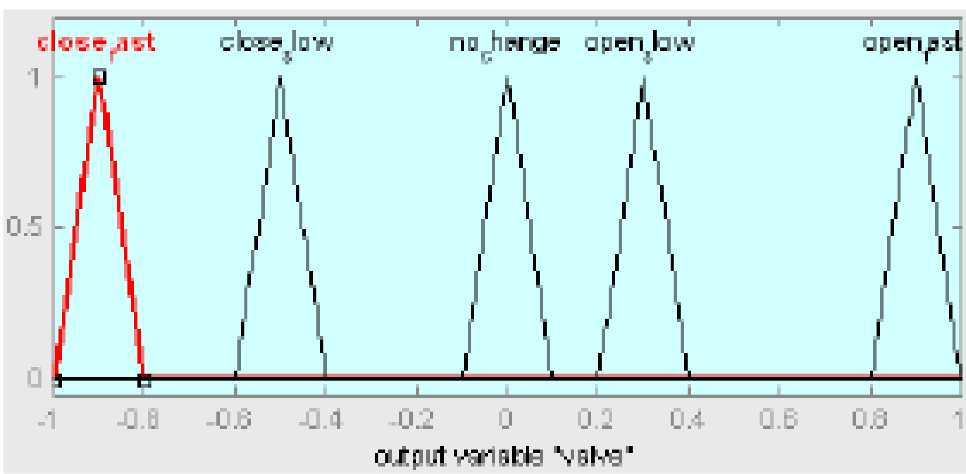

Fig.5 *Output Membership Function*

T A B L E 1 *Control Rules for Input and Output variables*

e-dot	Error		
	High	Okay	Low
Negative	none	open slow	none
None	close fast	no change	open fast
Positive	none	close slow	none

The defuzzification operation, in this paper, uses the centroid defuzzification method because of its implementation simplicity.

V. Experimental Setup and Results

The simplified of the level control system is shown in Fig.1 consists of a level transmitter and linear control valve. The level of the tank is control by using the fuzzy logic controller. The level transmitter is used for change the level to the current signal and change to voltage signal again. The height (H) of the level tank is 2 m, cross section area (A) of tank is 1 m^2, cross section area (a) of orifice is 0.05 m^2, the initial level height of tank is 0.5 m, and the overflow sensor distance from the top is zero.

In this paper shows level control by fuzzy logic controller compared with PID controller from 10 90% of the highest level tank and taking load by increase and decrease water level in the tank are tested.

The water level tank firstly controlled by the conventional controller i.e. PID controller, and parameters of PID controller has been tuned using zeigler-nichols technique. The parameters has been set to a definite value so that the water in the tank should be controlled upto the desired output. The response of the water level controlled by the PID controller is shown in figure 6.

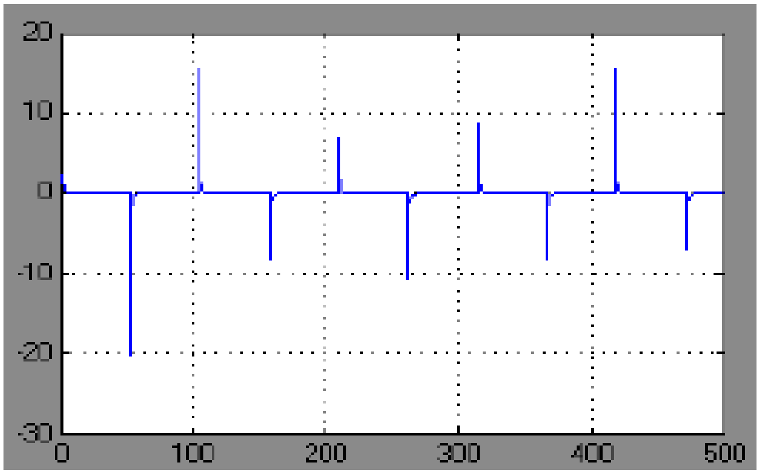

Fig.6 *Process Response using PID controller*

Now, the water level is controlled using the fuzzy logic technique. The purpose of experiments was to evaluate the efficiency of fuzzy controllers under different working conditions. i.e. changing reference signals, changing plant dynamics, when the throughput of output water is decreased twice.

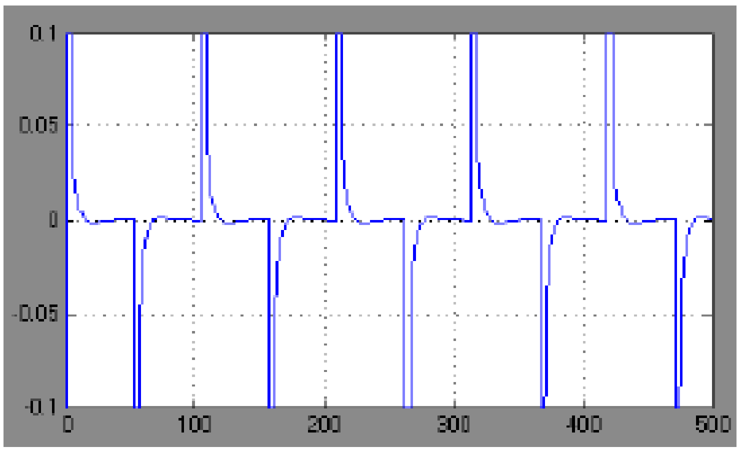

Fig. 7 *Response of change in error*

The saturation nonlinearity has been intentionally introduced within the range of 0.1 to -0.1, and the response of the change in error due to saturation nonlinearity is shown in figure 7. This rate of change of error and the error is directly fed to the fuzzy rule base block and rules shown in table 1 are implemented using Sugeno membership function. The response of the fuzzy controller is shown in figure 8.

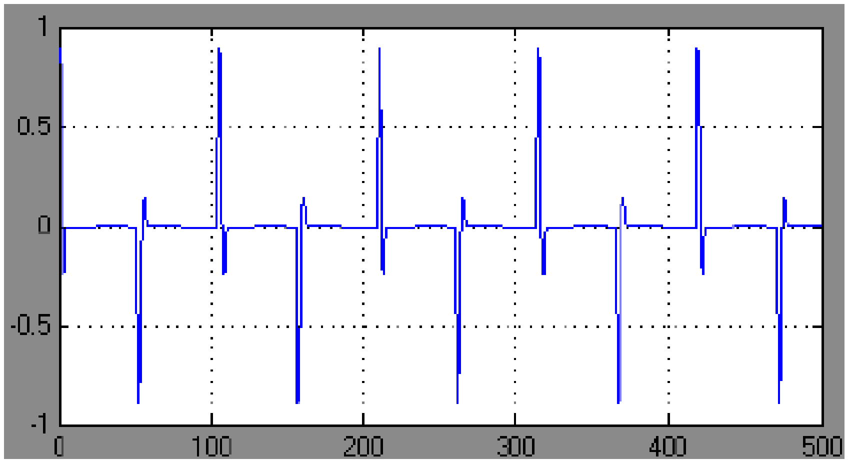

Fig.8 *Output of fuzzy logic controller*

The controlled water level in comparison with the input applied is shown in figure 9. The square wave of fixed amplitude and fixed frequency is applied to the system, and the rule base is design in such a manner so that water level try to oscillate around the desired specification. The interesting feature of water tank system is that the tank empties much more slowly than it fills up because of the specific value of the outflow diameter pipe. A PID controller does not have this capability.

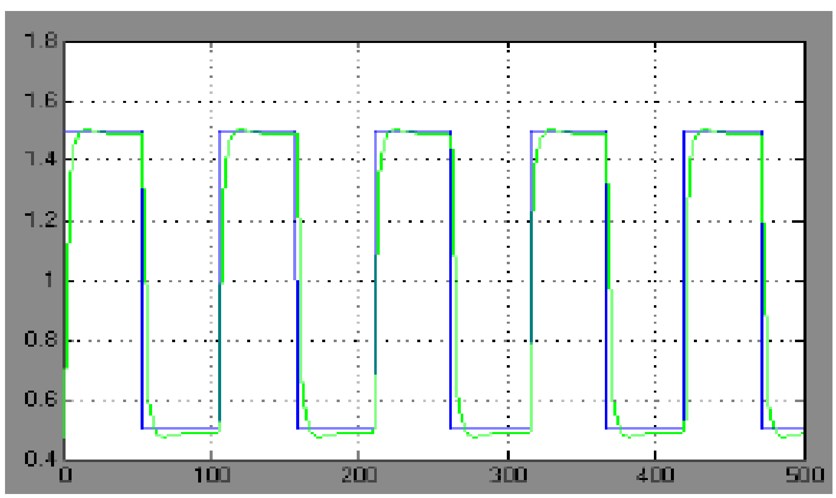

Fig.9 *Controlled Level of Water Tank*

VI. Conclusion

Fuzzy controller for water level control in the nonlinear plant have been synthesized. The sufficient efficiency of a fuzzy controller is shown experimentally, controlling the plant at different working conditions. It is experimentally proved that fuzzy controller are more powerful than conventional PID controller when working conditions and plant's dynamics changes in time. Both of fuzzy logic controller and PID controller give the smallest steady-state error.

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